

REMARKS/ARGUMENTS

In the Office Action, dated February 27, 2007, the examiner objected to claim 26 for being dependent on itself, which is corrected by this Amendment.

The examiner also rejected claims 10, 12 – 13, 19 – 31, and 40 – 59 under 35 U.S.C. 112, first paragraph, for several stated reasons in paragraph 5 of the Office Action regarding temperature and diffusivity rate and for several stated reasons in paragraph 6 of the Office Action regarding type and geometric parameters of metal. Claims 10, 12 – 13, 19 – 31, and 40 – 59 were also rejected under 35 U.S.C. 112, second paragraph, for lack of clarity in the word “initial” regarding before or after cooling.

Upon careful study of the examiner’s reasons for the rejections and a concurrent review of the specification, the applicant by this amendment has, *inter alia*, rearranged some of the description by moving two sentences from two of the paragraphs on page 15 of the specification to an earlier paragraph on page 14, where they fit more logically, removing several unnecessarily obfuscating phrases, and adding some explicit words that were implicit in the description before this amendment. It is believed that these changes may make the invention easier to understand, as will be discussed below in response to specific issues raised by the examiner.

Before addressing specific issues raised by the examiner in the Office Action, though, it may be helpful to review, as explained in the Background section of the specification, that hydrogen dissolved in welds causes cracking, embrittlement, weakening, and other detrimental changes in the welds. The diffusible fraction of hydrogen in a weld is generally accepted as a primary indicator of potential hydrogen damage to a welded joint, and the initial diffusible hydrogen concentration in the weld, i.e., the hydrogen concentration in a weld immediately after making the weld, is particularly useful in predicting damage due to hydrogen. Therefore, determination of initial diffusible hydrogen concentrations in welds is an important quality control

procedure. However, prior to this invention, there was no way of obtaining an initial diffusible hydrogen concentration from an actual weld in the field, i.e., from an actual weld on a bridge span, a building structure, a ship in drydock, a pipeline, etc., which cannot be sent to a lab for testing.

State of the art industry practice to determine initial diffusible hydrogen concentration in a weld as specified by the American Welding Society (ANSI/AWS A4.3 – 93), is a cumbersome and time-consuming process. It involves quenching four (4) samples or coupons of metal comprising the welds to low temperatures (-60 °C [-76 °F] or colder) to slow or stop diffusion of hydrogen out of the welds and holding them at such cold temperatures until they can be transported to a laboratory for testing within 72 hours to determine by laboratory methods what the initial diffusible hydrogen concentrations are in the welds. The protocols required by the American Welding Society's "Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding" (ANSI/AWS A4.3 – 93 (R2006)) requires that the weld test assembly shall be released from the copper clamping fixture and plunged into iced water within 5 seconds of extinguishing the arc and then agitated vigorously in the iced water for 20 to 30 seconds and then quickly transferred to a low-temperature liquid bath (- 60 °C [- 76 °F] or colder) for storage. The protocol in ANSI/AWS A4.3 – 93 (R2006) goes on to specify that, "The storage time for a test specimen shall be no longer than 72 hours (3 days) at – 60 °C (- 76 °F), nor 500 hours (21 days) at – 196 °C (- 320 °F), before loading into the analytical apparatus. The analytical apparatus, which can be, for example, something like the apparatus described in the U.S. Patent No. 4,192,175 to Godai et al. cited by the examiner in paragraph 5 of the Office Action, or a mercury displacement or other apparatus, where the weld specimen is heated and held for a long enough time to capture and measure all (or at least 90 percent of all) of the diffusible hydrogen that was initially present in the weld specimen for analysis in a gas chromatograph. The measured volume of hydrogen captured from the sample

weld is then divided by the mass of the weld and expressed in milliliters of hydrogen per 100 grams (ml/100 g) of weld metal.

In contrast, the present invention enables a person to determine the initial diffusible hydrogen concentration in a weld, not by the conventional laboratory methods based on capturing all of the hydrogen that can and does diffuse out of a weld sample, but by the novel and non-obvious concept of capturing only a small portion of the hydrogen that diffuses out of a weld over a much shorter time period, e.g. 10 to 30 minutes, starting at some arbitrary time T, for example, two hours, after the weld is made (see specification, page 17, lines 26 - 29) and from which a rate of hydrogen diffusion from the weld can be determined with a sampler apparatus, such as the diffusible hydrogen measuring apparatus 10 described in the specification. The steady state portion of the sensor assembly 20 response curve, i.e., slope, was first assumed and then verified to be proportional to the flux, e.g., diffusivity rate, of hydrogen from the weld, and it was tried and found experimentally that such slopes of curves generated with the sensor assembly 20 from weld samples correlate closely with initial diffusible hydrogen concentrations in the welds as determined with the standard AWS A4.3-93 protocol. See specification, page 14, line 25, through page 15, line 3.

In other words, it was found that for a weld sample of a particular metal made with a particular welding technique at a particular time T after the weld is made in particular environmental conditions, the slope of the particular response curve from the sensor assembly 20, i.e., diffusivity rate, is a result of what was the particular initial diffusible hydrogen concentration in the weld immediately after the weld was made. Of course, if the sensor assembly 20 was used on the same particular weld of the same particular metal with the same particular welding technique in the same particular environmental conditions, i.e., having the same initial diffusible hydrogen concentration, but at a different time T after the weld was made, then the response curve would have a different slope indicating a different diffusivity rate at that

different time T. Likewise, a different weld metal, a different welding technique, a different environmental condition, or a different initial diffusible hydrogen concentration would result in a different diffusivity rate, thus a different response curve slope.

Consequently, sets of example or reference curves can be made, either experimentally (empirically) or theoretically or both, for any particular kind of weld metal made with any particular welding technique in any particular environment for any particular time T after the weld is made (as long as the hydrogen flux is detectable by the sensor assembly, as explained on page 17, lines 26-29, of the specification, and the slopes of such curves will be indicative of particular initial diffusible hydrogen concentrations in such welds. However, the actual values of such initial diffusible hydrogen concentrations are not calculated from the response curve slopes. They are determined empirically with response curves from example welds and/or theoretically based on or conformed to such empirical data. Therefore, with such empirical and/or theoretical slope data available from the empirically and/or theoretical example or reference curves, a user of the measuring apparatus 10 can position the sensor assembly 20 on a particular kind of weld metal made with a particular welding technique in a particular environment at a particular time T after the weld is made to get a response curve slope from that weld, and, from the empirical and/or theoretical slope data, each of which correlates to a particular initial diffusible hydrogen concentration value, determine what was the initial diffusible hydrogen concentration in that weld.

With that short summary in mind, specific questions and issues raised by the examiner in the Office Action will be addressed below.

In paragraph 5 of the Office Action, the examiner makes several comments, including the following:

“Applicant has not taught how applicant’s calculation of initial diffusible hydrogen concentration, which is based on the hydrogen diffusivity rate, is influenced by temperature. . . . It would require undue experimentation for one of ordinary skill in the art to determine how to account for variations in temperature when calibrating the signal analyzer of the disclosed hydrogen sensor in accordance with the disclosure.”

However, the initial diffusible hydrogen concentration is not calculated from hydrogen diffusivity rate, as intimated by the examiner. On the contrary, as explained in the specification, page 14, line 25, through page 15, line 3, experiments were performed to correlate initial diffusible hydrogen concentrations to slopes of sensor assembly 20 response curves. Specifically, the sensor assembly 20 was used to generate response curves for example weld samples (see specification, page 14, line 32, through page 15, line 1). The steady state portion of those response curves was assumed to be proportional to the flux, e.g., diffusivity rate, of hydrogen from the weld sample (see specification, page 14, lines 30 – 31). However, the initial diffusible hydrogen concentration values for those welds were not calculated from those experimentally obtained slopes or diffusivity rates, as intimated by the above assertion by the examiner. On the contrary, the initial diffusible hydrogen concentrations were obtained from duplicate weld samples that were analyzed using a standard method, i.e., the American Welding Society AWS A4.3-93 protocol (see specification, page 15, lines 1 – 3), which, as explained above, involves extracting, capturing, and measuring all of the diffusible hydrogen from the duplicate weld samples regardless of temperature and/or diffusivity rate. “Duplicate weld samples”, of course, implies that the welds from which the initial diffusible hydrogen concentrations were obtained according to the AWS A4.3-93 protocol were substantially the same as the corresponding weld samples from which the slopes of sample curves were obtained experimentally, i.e., at least the same weld metal made with the same weld technique and in the same environment, as is understood by persons skilled in the art. Consequently, the initial diffusible hydrogen concentrations for the duplicate weld samples can be and were ascribed to the corresponding weld

samples from which the response curve slopes were obtained experimentally with the sensor assembly 20. In other words, the initial diffusible hydrogen concentrations for the corresponding weld samples were obtained empirically, not by calculations from hydrogen diffusivity rates. Consequently, temperature effects on diffusivity rates do not enter into the determinations of the initial diffusible hydrogen concentrations for the duplicate example weld samples, but they are simply manifested in the empirically obtained response curve slopes obtained from the duplicate weld samples. Therefore, the initial diffusible hydrogen concentration values obtained by the standard AWS A4.3 protocol from the duplicate example welds are simply ascribed to the corresponding example weld samples from which the response curve slopes are measured empirically, which naturally includes whatever effect temperature may have on such slopes. It is an empirical correlation of response curve slopes to initial diffusible hydrogen concentrations, not a calculation.

In paragraph 5 of the Office Action, the examiner also commented that, “It is unpredictable the extent to which the temperature or variations in temperature would affect the hydrogen diffusivity rate of a particular piece of metal.” Actually, relationship between temperature and hydrogen diffusivity rate is well-known and predictable. However, such predictions do not have to be made or quantified as part of this invention, because the slope correlation to initial diffusible hydrogen concentration is made empirically, as explained above, and the diffusivity rate to temperature relationship is whatever happens to exist for that particular kind of weld metal made with that particular weld technique in that particular environment at the particular time T after the weld is made.

Implicit in that empirical relationship, of course, is that, to be useful, a later weld for which initial diffusible hydrogen concentration is to be determined from the set of example empirically created slope-to-initial diffusible hydrogen concentration values, such later weld must be made with the same kind of weld metal with the same kind of welding technique in the same environment, and the hydrogen sample from such later

weld must be captured and measured with the sensor apparatus 20 at the same time T after the weld is made as was the case with the example empirically created curve slopes. For example, if the hydrogen measuring assembly 10 with its sampler apparatus 20 is to be used to determine the initial diffusible hydrogen concentration of a HSLA steel weld made with gas metal arc welding at a particular shield gas pressure in a room temperature environment, and if the sampler assembly 20 is placed on the weld for hydrogen collection and measurement at a time T of two hours after the weld is made to get a response curve with a slope, that slope would be useful only if there is a set of example empirically and/or theoretically created curve slopes available for comparison that were created for the same kind of HSLA steel weld material with the same kind of gas metal arc welding at the same shield gas pressure in a same room temperature environment and at the same time of two hours after the weld is made. If such conditions are duplicated, then the slope obtained from the later weld can be related to an initial diffusible hydrogen concentration value through the slopes of the set of example empirically created curves that have been correlated to example specific initial diffusible hydrogen concentrations for such welds, as explained in the specification, page 14, line 25, through page 15, line 3.

As also explained in the specification, in addition to creating sets of example curve slopes empirically, sets of example curve slopes can also be created theoretically with, for example, a diffusion equation based on a form of the error function equation with parameters that produce theoretical curves which are matched to actual response curves from the sensor assembly 20, as illustrated in Figure 4, thus also have slopes that correlate closely to initial diffusible hydrogen concentrations in such welds. See specification, page 15, lines 3 – 13. Persons skilled in the art know how to use the diffusion equation form of the error function to make such theoretical curves and then how to vary the parameters, such as different initial diffusible hydrogen concentration values, to create larger and/or additional sets of curve slopes correlated to such different initial diffusible hydrogen concentration values. Therefore, actual response curve slopes from later weld tests measured with the sensor assembly 20 can also be

compared to sets of such theoretically created example curve slopes for determination of initial diffusible hydrogen concentrations in such later welds. Again, however, such theoretically developed sets of curve slopes, like the empirically created sets of curve slopes, as explained above, are based on experimental actual response curves obtained from the same kinds of welds in the same kinds of environmental conditions as the welds to be tested later in order to be useful in determinations of initial diffusible hydrogen concentrations in such welds to be tested later with the sensor assembly 20.

Also in paragraph 5 of the Office Action, the examiner observed that, “Applicant teaches on page 19, lines 16 – 19, that the calibration step accounts for variations in temperature,” and then further asserted that, “It would require undue experimentation for one of ordinary skill in the art to determine how to account for variations in temperature when calibrating the signal analyzer.” In response, the applicant surmises that the examiner might have misconstrued the calibration as somehow compensating or adjusting diffusivity rates for different weld material temperatures, which is not the case. Therefore, it should be emphasized, first, that the calibration discussed in the two paragraphs beginning on page 18, line 26, and extending through page 19, line 19, of the specification is a further explanation of the calibration discussed on page 14, lines 10 – 24.

Second, that calibration is to correct for variations in light absorption by the sensing layer 28 as a result of variations in temperature of the sensor layer 28 from one use or measurement to the next (see specification, page 18, lines 31 – 32). In other words, for a given hydrogen concentration in the sample chamber 18, the tungsten oxide (WO_3) sensing layer 28 may absorb a first amount of light at one temperature, thereby resulting in a signal output of a first magnitude at such one temperature, whereas, at a different temperature, it may absorb a different amount of light and thereby result in a different magnitude signal output for the same hydrogen concentration in the sample chamber 18. Obviously, such temperature-dependent variations of light absorption by

the tungsten oxide (WO_3) sensing layer 28 need to be corrected in order to get consistent, accurate, and dependable hydrogen measurements for output curve slopes for the uses described above. The calibration described on page 14, lines 10 – 24, and continuing on page 18, line 26, through page 19, line 19, makes that needed correction.

Third, contrary to the examiner's assertion, calibration of the signal outputs from the sensor assembly 20 by use of a known calibration volume of hydrogen, as described in the specification, is quite straight forward, very understandable to persons having ordinary skill in the art, and would require little, if any, experimentation.

Most of the examiner's questions in paragraphs 6 and 8 of the Office Action are probably obviated by the remarks above, but they will be addressed below with an effort to not be too redundant. However, the examiner did raise another good point in paragraph 6 of the Office Action regarding the recitation in the specification, page 8, lines 16 – 19. The "known geometric and mass calculations" for determining the amount of material being sampled are essentially area and volume of a weld sample, which are junior high school level math, and the weld volume multiplied times density to get mass of the weld sample is a high school physics level calculation. Therefore, the trailing phrase, "as will be described in more detail below" is unnecessary for persons skilled in the art and has been eliminated by this amendment.

In paragraph 6 of the Office Action, the examiner also asked the question, "How do variables such as the type of metal, the thickness of the sample and the type of weld process influence the hydrogen diffusivity rate and also the calculation of the initial diffusible hydrogen concentration?" Again, as explained above, the only calculation of initial diffusible hydrogen concentration is according to the American Welding Society AWS A4.3 – 93 protocol, wherein the total hydrogen captured from the duplicate weld samples is divided by the mass of the weld samples to get the initial diffusible hydrogen concentrations in those duplicate weld samples in terms of

ml/100g and/or parts per million (ppm), which are high school physics level calculations. Those initial diffusible hydrogen concentration values obtained by the AWS A4.3 – 93 protocol for the duplicate weld samples were then ascribed to their counterpart weld samples from which response curve slopes were obtained with the sensor assembly 20 (see specification, page 14, line 25, through page 15, line 3). Thus, initial diffusible hydrogen concentrations for the counterpart weld samples were not calculated from the sensor assembly response curve slopes, as intimated by the examiner’s question. Instead, they were determined experimentally from the duplicate weld samples.

Also, as explained above, variables such as the type of metal, the thickness of the sample and the type of weld process do influence the hydrogen diffusivity rate, as surmised by the examiner, but those influences do not have to be calculated as intimated by the examiner’s question in paragraph 6 of the Office Action. On the contrary, those influences and the resulting hydrogen diffusivity rate are simply manifested in whatever response curve slope is generated empirically with the sampler assembly 20 from the particular weld that is being sampled or tested.

In paragraph 8 of the Office Action, the examiner asserted: (i) that it is unclear what the applicant means by the word “initial”; (ii) that a weld effuses hydrogen at a faster rate at higher temperatures; and (iii) that, “It is then important to determine whether applicant’s calculations refer to the concentration in the weld prior to or after cooling.” In response, the initial diffusible hydrogen concentration is described on page 15, lines 28 – 29, of the specification as that existing in the weld material immediately after weld completion. It is notable that the American Welding Society AWS A4.3 – 93 protocol requires that the weld sample be plunged into iced water within 5 seconds of extinguishing the arc and then quickly transferred to a low-temperature liquid bath (– 60 °C [– 76 °F] or colder) for storage in order to hold all or substantially all of the diffusible hydrogen in the weld until it can be transported to a laboratory for extraction, capture, and measurement to determine the initial diffusible

hydrogen concentration. Therefore, for the primary application of this invention, i.e., for determining initial diffusible hydrogen concentrations in welds, “initial” means immediately after the weld is made. However, “initial” could be defined and fixed at other times after a weld by doing the ice quench at another time after the weld so that the diffusible hydrogen available for capture and measurement is whatever remains in the weld at the time it is quenched in ice.

Again, there are no calculations to get from the sensor response curve slope or diffusivity rate to the initial diffusible hydrogen concentration. On the contrary, the initial diffusible hydrogen concentration is determined for duplicate welded samples according to a standard, e.g., the AWS A4.3 – 93 protocol, and then is ascribed to the calibrated sensor assembly 20 response curve slope obtained empirically from the counterpart of the duplicate welded sample. For the theoretically created curves from the diffusion equation form of the error function, the slopes of such theoretically created curves are conformed to the empirically created curve slopes, as illustrated by Figure 4, which were quantified by the AWS A4.3 – 93 protocol, so “initial” for the theoretical curves also means immediately after the weld is made.

New claims 60 – 64 recite the subject matter explained above in a slightly different way, which may help to elucidate the principles of the invention discussed. None of these new claims are shown in any prior art references cited and are believed to be clear and allowable under 35 U.S.C. 112, 35 U.S.C. 102, and 35 U.S.C. 103.

New claims 65 – 70 recite subject matter comparable to already presented claims 51 – 56, but with the subject matter recited in dependent claim 52 now recited in independent new claim 65. None of the prior art patents cited disclose any method of determining a diffusivity rate of hydrogen from a sample area of a metal specimen. Freeman teaches the use of a pressure sensor to sense change of pressure in a sample chamber that is indicative of changes in diffusivity rate of hydrogen from a sample area, but there is no way of determining from Freeman just what such diffusivity rate

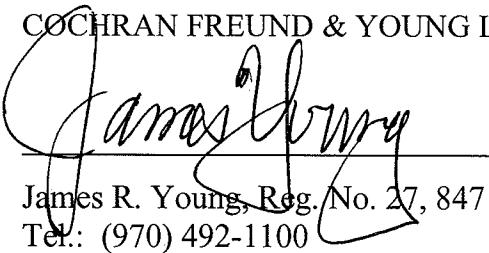
actually is. Therefore, while Freeman might show the positioning, allowing, and measuring elements of new claim 65, it does not teach or suggest the determining, multiplying, and dividing elements of the claim. While Bevenot et al. do not teach determining changes in hydrogen concentrations, their apparatus appears to be capable of doing so. Therefore, Bevenot et al. might be seen to enable persons skilled in the art to perform something similar to the measuring and determining elements of new claim 65. However, neither Freeman nor Bevenot et al., either alone or in combination, teach or fairly suggest the multiplying and dividing steps in new claim 65, and there is nothing other than hindsight application of the present invention to motivate persons skilled in the art to not only combine the hydrogen concentration sensing capability of Bevenot et al. with the sampler of Freeman, but then to also add the additional multiplying and dividing elements of new claim 65, because, without the teaching of the present invention, there is no reason for them to do so. Therefore, new independent claim 65 and the new dependent claims 66 – 70 are believed to be allowable over the prior art cited in this application.

All of the claims now presented are believed to be allowable for the reasons explained above, and the examiner is now requested to remove the rejections under 35 U.S.C. 112 first and second paragraphs and to grant an early allowance. If any issues remain to be resolved, the examiner is requested to contact the applicants' attorney at the telephone number listed below.

Respectfully submitted,

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Date: 5/29/07


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